# CHAPTER 1

# Tasks and Objectives for Modeling Behavior in Synthetic Environments

There are now numerous models of human behavior in Synthetic Environments (SEs), and they serve a multitude of uses. It is worthwhile considering where and how to improve these models to provice more realistic human behavior. This report provides a more recent review of work following Pew and Mavor (1998), and provides a detailed source of further ideas and suggestions. In addition to noting areas where models could be expanded to include more complete performance, we particularly draw the reader's attention both to the importance of the integration of models (and thus their reuse) and to the usability of models. We will argue that improved usability (and reusability) is necessary for these models to achieve their potential. We extend Pew and Mavor's results by examining architectures (e.g., COGENT, JACK, hybrid architectures) that were not included or available when Pew and Mavor compiled their report, and by summarizing several promising areas for further work that have arisen recently.

This report reflects the biases and specific expertise of the authors as they attempt to identify a wide range of potential problems and provide possible solutions. Some of the proposed projects are high risk and not all of the authors agree that these projects can be accomplished. All agree, however, that if possible, they would be rewarding. Given the diversity of human behavior, there remain many issues not covered here. For example, many aspects of teamwork are important but not examined here. Most of the systems and architectures reported here are continually evolving. Because of the rapid pace of development in this area, our review may underestimate the capabilities of these systems and several of our suggestions may already be incorporated in them.

## 1.1 The Role of Synthetic Forces

There are several commonly acknowledged uses of cognitive models in synthetic environments. These uses have included at least the range shown in Table 1.1. This is a wide set. Pew and Mavor (1998) focused on the application of synthetic forces to training partly because the major applications and successes of synthetic forces have been in this domain. Further uses of synthetic forces have been outlined in other reviews (Computer Science and Telecommunications Board, 1997; Lucas & Goss, 1999; Synthetic Environments Management Board, 1998).

**Table 1.1: Potential Uses of Models in Synthetic Force Environments**

- Training leaders
- Joint and combined training
- Training other personnel (e.g., support and logistics)
- Testing existing doctrine
- Testing possible future procurements
- Testing new doctrine
- Serving as a formal, runnable description of doctrine

The user community for synthetic forces would be better served if all these uses were supported by a single system or approach. Currently, the models of behavior in these systems have often been developed without a long-term plan, and are only usable within the simulation for which they were developed. Historically, few single systems have supported more than one or two of the uses noted in Table 1.1. This is wasteful and can lead to different behaviors being taught or used in different simulations when they should be exactly the same behavior. The use of the Distributed Interactive Simulation (DIS) protocol for distributed simulation is a step toward integration, but it does not apply to behavior itself.

While having a single system or approach is highly desirable, there are good reasons why multiple systems are currently used (in addition to a multitude of bad reasons as well). Perhaps the most important reason why there are multiple models of behavior is that existing approaches to modeling cannot support all of the uses in Table 1.1 equally well. Models that focus on aggregate, or large unit behavior, do not support low-level simulations very well. Models that predict average behavior are much less useful for practicing tactics and procedures. Models that are good for training provide detailed data that have to be extensively summarized and aggregated to be of use to planners. Planners and evaluators, for example, may find useful data in large simulations such as the Purple Link exercise, part of STOW97 (further information is available from Ceranowicz, 1998, as well as from www.stricom.army.mil/STRICOM/DRSTRICOM/DOCATS/), although such simulations cannot yet be convened within an afternoon or even a week to examine how a new platform performs. This report will makes suggestions on all of these levels, but it does not intend to be comprehensive.

## 1.2 Definition of Terms

There are several terms used in this report that have meanings specific to the domain of behavioral modeling. The term model, for example, will refer exclusively to cognitive models, and the term "simulation" will refer exclusively to task simulations. We review these terms here, starting by introducing synthetic forces. Modular Semi-Automated Forces (ModSAF) is briefly explained to provide a common system as a point of reference. We then define the terms we will use with respect to models of behavior.

### 1.2.1 Synthetic Forces

Synthetic forces exist in military simulations, sometimes alongside real forces that have been instrumented and linked to the simulation. There are now synthetic force simulations covering all of the armed services. Synthetic forces can be separated into two components, physical and behavioral. The physical aspects represent the movement and state of platforms (objects) in the simulation, including such aspects as maximum speed and the set of actions that can be performed in the world. The physical aspects provide constraints on behavior. Simulations of the physical aspects are fairly complete now for most purposes, although they remain important in their own right (Computer Science and Telecommunications Board, 1997; Synthetic Environments Management Board, 1998).

The behavioral aspects of a synthetic force platform determine where, when, and how it performs the physical actions, that is, its behavior. Many human and entity behaviors can be simulated, such as movement and attack, but behavior has been less veridically modeled than physical performance. The next step to increase realism is not only to include further intelligent behavior but also to match more closely the timing and sequence of human behavior when performing the same tasks.

### 1.2.2 Modular Semi-Automated Forces

Modular Semi-Automated Forces (ModSAF) is a system for simulating entities (platforms) on a simulated battlefield (Loral, 1995). It is perhaps the most widely used behavioral simulator in military synthetic environments. The goal of ModSAF is to replicate the behavior of simulated platforms in sufficient detail to provide useful training and simulation of tactics.

ModSAF includes the ability to simulate the most common types of physical platforms, such as a tank, and external effects on those platforms, like weather and smoke. The terrain is defined in a separate database, which is shared by other simulators in the same exercise using the DIS simulation protocol. Multiple platforms can be simulated by a single ModSAF system.

The local platforms interact with remote platforms by exchanging approximately 20 different types of information packets. Examples of packet types include announcing where the platform is located (the other platforms compute whether the originator can be seen), where radar is being emitted, and where shots are being fired. Thus, the features of the packets vary. Each simulation is responsible for updating its own position and computing what to do with the information in each packet, so that a tank does not directly shoot another tank, for example. Attackers send out projectile packets and the target tank computes that it would be damaged by their projectiles.

Some semi-intelligent behaviors are included in ModSAF through a set of about 20 different simple scripts. These scripts support such activities as moving between two points, hiding, and patrolling.

ModSAF is a large system. It can be compiled into several major versions, including versions to test networks and specific versions for each service. The terrain databases each include up to 1 gigabyte of data. In 1999, simulating multiple entities required a relatively fast workstation (100 MHz+) with a reasonable amount of memory (32 MB+).

A major problem is usability as ModSAF is large and has a complicated syntax. Users report problems learning and using it. A better way to provide its functionality needs to be found or its usability needs to be improved directly.

### 1.2.3 Frameworks, Theories, Models, and Cognitive Architectures

It is common in cognitive science to differentiate between several levels of theorizing (e.g., Anderson, 1983; 1993, chap. 1) and defining these levels now will help us in the remainder of this report. *Framework* refers to the specification of a few broad principles, with too many details left unspecified to be able to make empirical predictions. For example, the idea that human cognition acts as a production system offers a framework for studying the human mind.

*Theory* adds more precision to frameworks, and describes data structures and mechanisms that at least allow qualitative predictions to be made. For example, the production system principles presented in Newell and Simon (1972) form a theory of human cognition.

*Models* are theories implemented as computer programs or represented mathematically to apply to specific situations or types of situations. While generally more limited in their domain of application than theories, models typically provide more accurate, quantitative predictions.

*Cognitive architecture* has two meanings: (1) specifications of the main modules and mechanisms underlying human cognition, and (2) the computer program implementing these specifications. These meanings are separate and distinct but usually are used as equivalent. Cognitive architectures, as proposed by Newell (1990), offer a platform for developing cognitive models rapidly while keeping the theoretical coherence between these models intact. These cognitive architectures are often seen as equivalent to Unified Theories of Cognition (UTC), a way to pull all that is known about cognition into a single theory. In Appendix B we include brief descriptions of two commonly used cognitive architectures, ACT-R and Soar.

There exists no generally agreed definition of *hybrid architectures*. Some use the term when a cognitive architecture includes symbolic features (e.g., a production system) as well as non-symbolic features (e.g., neural net spreading of activation among memory elements); others, such as Pew and Mavor (1998), use the term when two or more architectures of any kind are combined (e.g., Soar and EPIC). We use the latter definition here because this type of hybrid architecture has become more important and more frequently used.

When comparing theoretical proposals, it is essential to keep in mind the level at which the proposals were formulated. Typically, a framework will cover a large amount of empirical regularities without specifying many details, while a model will cover a small amount of data with great precision. It is generally agreed that models are more useful scientifically than theories or frameworks because they make clear-cut predictions that can be tested with empirical data, and hence, are less amenable to ad hoc explanations (Popper, 1959). Models are, however, harder to create and use.

## 1.3 Summary of Modeling Human and Organizational Behavior

While the reader is likely to have seen Pew and Mavor's (1998) *Modeling Human and Organizational Behavior*, we briefly review it here to provide background for readers not familiar with it and to provide some useful context. In their book, Pew and Mavor review the state of the art in human-behavior representation as applied to military simulations, with an emphasis on cognitive, team, and organizational behavior. Their book is based on a panel that met for 18 months and drew extensively on a wide range of researchers. It is available as a hardcopy book, as well as online (books.nap.edu/catalog/6173.html).

Pew and Mavor look not just at representing behavior, but also at methods for generating behavior. They provide a review of the uses of models of behavior in synthetic environments. They include a review of the major synthetic environments in use by the U.S. military. These environments are examples of the range of current and potential uses and levels of simulation.

Their book provides a useful summary of integrated (cognitive) architectures. It is comprehensive and clear enough that we have used it to teach undergraduate students. Their summary includes a table comparing the architectures. We will apply the same table to review several additional architectures.

Their book also reviews the important areas to modeling human behavior in synthetic environments. This is a very wide range, encompassing nearly all of human behavior. Their book reviews attention and multi-tasking, memory and learning, human decision making, situation awareness, planning, behavior moderators (such as fatigue and emotions), organizational (small group) behavior, and information warfare (e.g., how the order of information presentation influences decision making). Their book concludes with a framework for developing models of human behavior followed by conclusions and recommendations. Each of these reviews is clearly written and limited only by the space it is allowed. The reviews are quite positive, suggesting that major aspects of behavior are either already being modeled, or can and will be modeled within a few years. This positive tone is in stark contrast to a similar review a decade earlier, which could only note open questions (Elkind, Card, Hochberg, & Huey, 1990).

## 1.4 What *Modeling Human and Organizational Behavior* Does Well

Pew and Mavor's book is a useful and seminal book for psychology and modeling. Their book is useful because the reviews it provides, while they could be extended, are unusually clear and comprehensive, covering the full range of relevant behavior. It could serve as a useful textbook for professionals in other areas to teach them current results and problems in the areas of psychology and modeling.

Their book is seminal because the authors lay out a complete review of cognition that is widely usable. While their review is similar to Newell's (1990) and Anderson and Lebiere's (1998) reviews, Pew and Mavor's review is not situated within a single architecture; the result is a more global and only slightly less-directed view.

The reviews of the models and data to be modeled together, because of their scope and potential impact, constitute a call to arms for modelers of synthetic forces. The juxtaposition of the data and ways to model them is enticing and exciting. This approach of modeling behavior will significantly influence psychology in general if the modeling work continues to be successful. Models of synthetic forces in the near future will subsume enough general psychology data that they will simply represent the best models in psychology.

## 1.5 Where *Modeling Human and Organizational Behavior* Can Be Improved

There are surprisingly few problems with Pew and Mavor's review. However, they do not review all of the possible regularities of human behavior. We will add a few additional important regularities and provide further arguments to support many of their main conclusions. They could have referenced, for example, the *Handbook of Perception and Human Performance* (Boff, Kaufman, & Thomas, 1986) and the *Engineering Data Compendium* (Boff & Lincoln, 1988) for a wide-ranging list of existing general regularities in perception and performance (the latter reference has also been put into a CD-Rom version as well, see iac.dtic.mil/hsiac/products/cashe/cashe.html). In the area of human decision making, Dawes' (1994) review is also valuable. Pew and Mavor do not cite a quite relevant report on how this type of modeling is also being developed as entertainment (Computer Science and Telecommunications Board, 1997), and, not surprisingly, they could not report a concurrent similar United Kingdom review (Synthetic Environments Management Board, 1998).

On a high level and early on, they explicitly note that they will not review the usability of behavioral models. We will argue that improved usability is necessary for these models to achieve their potential.

They do not have the space to review all the integrative (cognitive) architectures. While it would be unfair to call this book dated at this point in time, there are already a few architectures worth considering that were not available to them.

They do not dwell on the ability to describe human behavior, instead they focus on how to generate it. There remains some need to be able to describe the behavior before generating it, which we will take up below.

Finally, they did not have the space to lay out very detailed projects to fulfill their short-, medium-, and long-term goals. We provide a more detailed, but still incomplete, set.

## 1.6 Structure of This Report

Chapter 2 provides amplifications, updates, and additions to Pew and Mavor's list of psychological regularities that should be included in models of human behavior. Chapter 3 notes problems integrating models with simulations as well as problems integrating them with each other to make larger, more complete models. Chapter 4 takes up the issues surrounding usability of behavioral models. Usability of the models themselves was considered to be outside the scope of Pew and Mavor's report (1998, p. 10). We will argue that improving the usability of these models by their creators and other analysts is not only desirable, but necessary for the success of modeling itself. Chapter 5 considers new techniques and cognitive architectures for modeling human behavior in synthetic environments with respect to the aims of the previous two chapters. Chapter 6 concludes with a list of projects to address problems identified in Chapters 2, 3, and 4 based on the techniques and architectures in Chapter 5.